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TECHNICAL NOTE

D-438

PROBLEMS INVOLVED IN AN EMERGENCY METHOD OF GUIDING
A GLIDING VEHICLE FROM HIGH ALTITUDES
TO A HIGH KEY POSITION

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SUMMARY

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An investigation has been conducted to determine the problems involved in an emergency method of guiding a gliding vehicle from high altitudes to a high key position (initial position) above a landing field. A jet airplane in a simulated flameout condition, conventional ground-tracking radar, and a scaled wire for guidance programming on the radar plotting board were used in the tests. Starting test altitudes varied from 30,000 feet to 46,500 feet, and starting positions ranged 8.4 to 67 nautical miles from the high key. Specified altitudes of the high key were 12,000, 10,000 or 4,000 feet. Lift-drag ratios of the aircraft of either 17, 16, or 6 were held constant during any given flight; however, for a few flights the lift-drag ratio was varied from 11 to 6. Indicated airspeeds were held constant at either 160 or 250 knots.

Results from these tests indicate that a gliding vehicle having a lift-drag ratio of 16 and an indicated approach speed of 160 knots can be guided to within 800 feet vertically and 2,400 feet laterally of a high key position. When the lift-drag ratio of the vehicle is reduced to 6 and the indicated approach speed is raised to 250 knots, the radar controller was able to guide the vehicle to within 2,400 feet vertically and 5,200 feet laterally of the high key. It was also found that radar stations which give only azimuth-distance information could control the glide path of a gliding vehicle as well as stations that receive azimuth-distance-altitude information, provided that altitude information is supplied by the pilot.

INTRODUCTION

There have been several flight investigations of the problems associated with the landing technique for gliding vehicles, particularly those with low lift-drag ratios. These investigations (see, for example,

refs. 1 to 5) have primarily been concerned with the approach pattern and the flare prior to touchdown of the landing vehicle.

In addition to the landing techniques for gliding vehicles, approach techniques for that portion of flight between 100,000 feet and the high key are also of sufficient importance for winged reentry-type vehicles to warrant investigation. It is during this phase of operation that the vehicle must be controlled, either through automatic guidance equipment located on the ground and in the aircraft or by the human pilot, so that the vehicle can be directed to an acceptable landing field. Should the vehicle arrive at 100,000 feet at such a location as to be unable to glide to the preselected landing field, the pilot, by necessity, will be required to assume command of the vehicle and guide it to a suitable field located within gliding range. As pointed out in reference 3, human judgment for such a task cannot be relied upon and a poor recovery probability may be expected for the gliding winged reentry vehicle should its arrival at 100,000 feet occur outside boundaries necessary to reach the preselected airfield.

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One method of aiding the pilot in guiding a gliding vehicle to an alternate field has been investigated at the Langley Research Center. While the lift-drag-ratio range considered in the investigation is higher than for proposed reentry vehicles, it is believed that the problems encountered may be typical of those which would be faced - in an emergency situation - by a reentry vehicle. Two jet airplanes, a conventional ground-tracking radar installation, and a scaled wire for guidance programming on the radar plotting board were used in the investigation. The aircraft was placed in a simulated flamecut condition at random locations and altitudes from a landing field, then ground-tracking radar with the aid of the guide wire was used to direct the aircraft to a high key position above the landing field. Control of altitude along a prescribed path was effected by either lengthening or shortening the aircraft track relative to the guide path, or through use of the aircraft speed brakes. Starting test altitudes varied from 30,000 feet to 46,500 feet, and starting positions ranged from 8.4 to 67 nautical miles from the high key. Specified altitudes of the high key were 12,000, 10,000, or 4,000 feet. Lift-drag ratios of the aircraft of either 17, 16, or 6 were held constant during any given flight; however, for a few flights the lift-drag ratio was varied from 11 to 6. Indicated airspeeds were held constant at either 160 or 250 knots. The results of 22 controlled approaches to the high key are presented herein and are the subject of this report.

DEFINITIONS AND SYMBOLS

Nomenclature:

Guide wire A flexible wire about 1/8 inch in diameter, scaled in glide distance for altitude increments from 1,000 to 3,000 feet to match the descent rate of an aircraft and the radar plotting-board scale.

L Guide path The trace of the guide wire on the radar plotting
1 board. This path is used as a reference for
0 checking and controlling the progress of the
6 aircraft to the high key.
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High key An invisible point, generally over an airfield, which is used by a pilot during a flameout approach as an initial altitude and airspeed check prior to commencing a prescribed pattern for a landing.

Radar controller The person who operates the radar console, interprets signal information, and commands aircraft directional headings.

Radio director The person who relays directional-heading commands to the pilot.

Steer Magnetic heading which, if flown by the aircraft, will take it directly to the high key.

Vector Magnetic heading change command given to the pilot by the radio director or radar controller.

Symbols:

L/D lift-drag ratio

V_i indicated air speed, knots

γ glide-path angle, deg

APPARATUS

Aircraft

Two jet aircraft (shown in fig. 1) were used during the investigation. Photographs of a tandem-seated jet trainer (fig. 1(a)), and a single-seated, high-performance fighter (fig. 1(b)) are presented. Attitude control of both aircraft was maintained by conventional aerodynamic control surfaces.

Radar

Ground radar equipment, from which aircraft position and altitude information were obtained, consisted of standard production AN/FPS-16 and SCR-584 models. Tracking was accomplished by either skin reflection or by beacon-signal reception. Position and altitude information sensed by the radar were displayed on a table 30 inches by 30 inches and were indicated on recording paper by ink pens that marked at 1-second time intervals. The radar station was located about 5 nautical miles from the high key position. A photograph of the radar plotting board is shown in figure 2.

Guide Wire

In order to provide the radar controller with a means of guiding the aircraft to the high key, an effective lift-drag ratio was determined from flight tests for a given configuration of the aircraft to be directed. By use of the relationship that $D/L = \tan \gamma$, where γ is the glide-path angle, and a knowledge of the scale factor to be used on the radar plotting board, a wire was marked with a length equal to the scaled distance the aircraft would glide from its maximum altitude to the altitude at the high key. This length represented a straight and level glide and did not take into account decreased lift-drag ratios that resulted when the aircraft banked or turned nor head or tail winds encountered in the descent. In addition, the wire was marked at distances corresponding to altitude losses of 1,000, 2,000, or 3,000 feet to provide check points as the problem progressed. A photograph of two of the guide wires used in the tests is shown in figure 3.

Radio

Voice communications between the radar controller and the aircraft being directed were provided by conventional UHF radio equipment.

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TESTS

General Description

Radar-directed approaches to the high key were conducted for aircraft altitudes ranging from 46,500 feet to 30,000 feet. Geographical locations of the aircraft at the start of the problem were varied from 8.4 to a maximum of 67 nautical miles from the high key. Aircraft headings at the start of the problem were random, varying from inbound to the high key to outbound away from the high key. Lift-drag ratios were held constant for each flight investigated; however, over the range of tests this ratio was varied from 17 to 6. Indicated airspeeds were held constant throughout each flight at either 160 or 250 knots.

Procedure

The start of the test was initiated by either the pilot or radar controller when radar contact with the airplane was established. The radar plotting pens were turned off to clear the board. The guide wire was placed on the radar board so that the altitude mark of the wire was over the starting position of the airplane and corresponded to the altitude and heading of the airplane at this starting position. The free end of the guide wire was placed at the high key with the desired altitude mark as the terminal position. The slack portion of the guide wire between the starting and terminal positions was then arranged to provide a maximum turning radius and a minimum number of turns for the aircraft to arrive over the high key position on the desired heading. The altitude marks and the path along which the aircraft was to be guided were traced on the recording paper, the wire was removed, and the recording pens were turned on. The radar controller then used the traced path as a reference for directing and checking the progress of the aircraft toward the high key. The foregoing procedure was repeated when the aircraft was near enough to the high key to permit switching to a more sensitive scale on the radar plotting board.

RESULTS AND DISCUSSION

The results of this investigation are discussed in three phases. The first phase includes high L/D, low-speed approaches; the second phase includes high L/D, high-speed approaches; and the third phase includes low L/D, high-speed approaches. A listing of all approaches investigated is presented in table I. The starting position of each flight relative to the high key is shown in figure 4, and the arrival position relative to the high key is shown in figure 5.

High L/D, Low-Speed Approaches

The first series of flights investigated (flights 1 to 10) were simplified as much as possible to gain a feel for the problems that were expected. For these flights, the configuration of the aircraft was adjusted to give an effective lift-drag ratio of about 16, and the approach speed was held constant at 160 knots. Starting positions were varied from 67 to 8.4 nautical miles from the high key, and starting altitudes were varied from 35,000 to 30,000 feet. Altitude control was affected by directing the aircraft along a path either longer or shorter than the guide path. Aircraft directional commands were issued by the radar controller through the radio director to the pilot. About 15 minutes were available to the radar controller for directional guidance of the aircraft, and about 1 additional minute was expended for each of the two times during each flight that the guide path was laid, traced, and marked on the radar plotting board. A reproduction of the radar plot of flight 4 in this series of tests is shown in figure 6.

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Operational problems.- Generally, no serious problems were encountered in this first series of flights; however, several minor problems were apparent. The first of these problems concerned control of the guide wire. During the first flight only one person was used to position the guide wire on the radar board. Though awkward, this was satisfactory for the initial portion of the flight when the coarse scale of the radar plotting board was used. When the aircraft reached a position which allowed the radar controller to switch to a more sensitive scale, the stiffness of the guide wire caused the person positioning the wire to lose control of it. As a result, the radar controller was forced to direct the movement of the aircraft without benefit of the guide path. This resulted in an arrival of the aircraft at the high key with an excess altitude of 2,500 feet. On subsequent flights, this problem was overcome by using two men to control the laying of the guide wire. One man handled the positioning of the initial portion of the guide path and the second man controlled the positioning of the terminal portion of the path.

Difficulty was also experienced with properly planning the path of the guide wire. In one instance, the guide path was routed such that the shift to a more sensitive scale was not possible until only about 2,000 to 4,000 feet of altitude remained for vector control. This delay caused considerable maneuvering of the aircraft during the final approach to the high key and was objectionable to the pilots. Proper guide-path routing should allow transfer to the high-sensitivity scale when the aircraft still has 8,000 to 10,000 feet of altitude available for control purposes.

Another problem which occurred during the initial flights was confusion that resulted from misidentification of altitude marks along the

guide path. This misidentification was found on both the coarse-scale and the fine-scale guide paths. The discrepancy was believed to result from anxiety on the part of the radar controller to mark the guide path so that the recording pens and, consequently, the aircraft guide-path information could be reactivated as quickly as possible. Altitude marks along the guide path are as important as the guide path itself, and care should be taken to insure that the marks are properly identified.

In addition to radar-plot-initiated starts of the problem, pilot-initiated starts were also made to simulate random pickup of the signal from a reentry craft. The radar controller experienced no additional difficulties with this type of problem than were experienced when radar plot initiated the start of the problem.

In the course of the tests, it was also found that radar altitude information was not necessary. Adequate guidance of the aircraft can be accomplished by the radar controller provided indicated altitudes are transmitted by the pilot at each 2,000- or 3,000-foot interval during the descent. It would seem from this finding that, provided two-way radio communications are available, radar stations capable of receiving only azimuth-distance information would be able to adequately control the glide path of a gliding vehicle.

Guidance and pilot's opinions.- The maximum vertical deviation from the high key for any of these 10 flights was 800 feet, and the maximum lateral displacement for any of these flights was 2,400 feet.

Pilot opinions for this series of flights were confined generally to the lack of chatter from the radio director. Elapsed times of up to $1\frac{3}{4}$ minutes between communications were common for the first two flights. In addition to directional commands to the pilot, information such as steers to take in the event of communications failure, and wind and weather information at the field of intended landing were desired by the pilots.

High L/D, High-Speed Approaches

The effect of glide velocity upon the ability of the radar controller to successfully vector the aircraft to the high key was investigated by maintaining an effective lift-drag ratio of 17 and increasing the glide speed to 250 knots indicated airspeed. Starting positions were varied from 40 to 44 nautical miles from the high key, and starting altitudes were varied from 33,000 feet to 34,500 feet. Altitude control of the aircraft by the radar controller was done in a manner similar to the procedure used in the high L/D, low-speed flights; however, a slight

change in the procedure was made in flight 13 and is discussed in the following section. For these flights, about 10 minutes were available to the radar controller for directional guidance of the aircraft. Laying, tracing, and marking the guide path on the radar plotting board required about 1 minute for each of the two times during a flight this was done. The results of these high-speed approaches are tabulated in table I (flights 11, 12, and 13). A reproduction of the radar plot of flight 12 is given in figure 7.

Operational problems.- For these flights, the radar controller experienced considerably more difficulty in correctly positioning the aircraft at the high key than with the preceding flights which were made at lower approach speeds. While sufficient time was available for directional, and therefore altitude, control, the radar controller had difficulty in anticipating the track of the aircraft sufficiently to compensate for the high approach speed. By the time commands for directional changes were relayed to the pilot, the point of intended turn had been overshot. This error was compounded as the flight progressed. The portion of flight 12 (fig. 7) between 18,000 feet and the high key is an example of guidance lag by the radar controller.

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An effort was made in flight 13 to minimize guidance delays by giving directional commands directly to the pilot from the radar controller and eliminating the task of the radio director. Some small improvement in altitude control was noted, as can be seen by comparing the results of flights 11 and 12 with flight 13 in table I and in figure 5(b).

Guidance and pilot's opinions.- The maximum vertical deviation from the high key for flights 11, 12, and 13 was 800 feet, and the maximum lateral displacement for any of these flights was 400 feet.

Pilot opinions on these flights included criticism of the frequency with which heading changes were given by the radar controller. During prolonged turns, directional change commands were given to the pilot prior to his completing the turn prescribed by the previous heading change command. This complaint was remedied by a control method described in the following section.

Low L/D, High-Speed Approaches

The results of nine low L/D, high-speed approaches are given in table I (flights 14 through 22) and in figure 5(c). The lift-drag ratio for flights 14 to 18 was 6. In flights 19 to 22, this ratio was either 6, 10, or 11. Indicated airspeeds for all approaches were held constant at 250 knots. Starting distances from the high key ranged from 9.4 to 44.4 nautical miles, and starting altitudes varied from 34,000 to

46,500 feet. Altitude control of the aircraft by the radar controller in flights 14 to 18 was exercised in a manner similar to that used in the high L/D, high-speed approaches; however, in flights 19 to 22, altitude control was attempted by using speed brakes and an intermediate-length guide wire. About 4 minutes were available for directional guidance of the aircraft in flights 14 to 18, and from 6 to 8 minutes in flights 19 to 22. A reproduction of the radar plot of flight 16 is shown in figure 8.

L Operational problems.- The amount of time available to the control-
1 ler for directional guidance of the aircraft appears to be a contributing
0 factor in his ability to effect altitude control of the aircraft. The
6 high rate of descent, 5,000 feet per minute, of the aircraft in flights 14
3 to 18 allowed only 4 minutes for guidance commands. The time was less
 than one-third of that available for altitude control in the high L/D,
 low-speed approaches; this limitation practically eliminated any chance
 to maneuver the aircraft for altitude corrections when deviations from
 the altitudes prescribed by the guide wire occurred.

 Mistakes by personnel laying the guide path and by the radar con-
 troller accounted for the low altitudes at the high key in flights 15
 and 17. In flight 15, the terminal position of the guide wire was inad-
 vertently placed on the geographical location of the coarse-scale high
 key position instead of the fine-scale high key position. The mistake
 was not discovered until the aircraft had passed through 18,000 feet.
 Diverting the aircraft to the fine-scale high key position compelled it
 to traverse about 4 additional nautical miles which resulted in a low
 arrival at the high key. A wrong turn was given by the radar controller
 at a crucial point in flight 17 which placed the aircraft outside the
 guide path away from the high key. Inasmuch as the guide path from this
 point to the high key was very nearly a straight line, there was no
 chance to vector the aircraft inside the guide path to make up the lost
 altitude.

 As would be expected, radio communications are an important contri-
 bution to the success or failure of a guidance problem. If the frequency
 being used is cluttered with unrelated transmissions, such as communica-
 tions between other aircraft using this frequency but not connected with
 the tests, blockage of guidance instructions is likely to occur. A prob-
 lem such as this did occur during flights 18 and 19 when a radio failure
 forced the radar controller to use a tactical frequency common to other
 aircraft in the area. Increased vigilance by the radar controller was
 mandatory in monitoring path and altitude progress of the guided aircraft
 so that guidance instructions which were blocked could be detected and
 corrected as quickly as possible.

 Flights 18 and 19 in the low L/D, high-speed approaches, were con-
 trolled by the project engineer who had never had radar experience prior

to controlling these two flights. While the guidance did not have the finesse exhibited by the regular radar controller, the results as seen in table I were no worse than for flights controlled by the regular operator. It is therefore believed that with simple instructions any radar operator could control the flight of a gliding vehicle within the boundaries shown in these tests.

Directional guidance.- In an attempt to improve altitude control, a change was made in the method of directional guidance control. It was noted that during any prolonged turn the radar controller was continually giving vector heading changes to direct the aircraft along the desired guide path. Considerable concentration on the part of the radar controller was required to follow the progress of the aircraft, to remember what the last magnetic heading command was, and to decide what the new heading command should be. For all flights after flight 17, commands for directional changes were given as "10° (or 20° or 30°) right (or left) bank," and for straight flight, "roll out" or "wings level." This procedure was favored by both the radar controller and by the pilots. Although there were no startling improvements in arrival altitude at the high key, the ease of directional control of the aircraft was definitely improved.

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Altitude control through speed-brake operation.- An alteration in the method of controlling aircraft altitude was used in flights 19 to 22. An intermediate guide wire, having a length proportional to an L/D midway between that which the aircraft would have with the speed brakes extended and that with the speed brakes retracted, was used for final controlling of the last 10,000 feet of altitude to the high key. By use of this intermediate guide-wire length, adjustments in aircraft altitudes to conform with guide-wire altitudes were accomplished by manipulations of the speed brakes. If the guide wire indicated the aircraft was too high, the radar controller requested speed-brake extension, and if the aircraft was too low, speed-brake retraction.

Two problems were encountered using this particular method of altitude control. In flights 19 and 21, the aircraft arrived low at the high key as a direct result of the radar controller allowing the speed brakes to remain extended for an excessive period of time. The rate of sink during transition from speed brakes extended to speed brakes retracted was difficult for the radar controller to judge. By pulsing the speed brakes, that is, opening them for a short period of time - 3 to 7 seconds - then closing them, better altitude control was realized by the controller.

The other factor relative to altitude control with the use of the intermediate-length wire was the false sense of well-being which the radar controller experienced when the altitude of the guide wire and the actual altitude of the aircraft were the same. When this condition occurred, the aircraft was either ascending or descending through the path prescribed

by the guide wire, and instead of indicating "all's well," as with the first method of control (normal-length guide wire), signaled that a departure from the desired path was imminent and that a change in speed-brake position was necessary. Had the radar controller never used the normal-length guide wire, this difficulty probably would not have occurred.

Guidance and pilot's opinions.- For the low L/D, high-speed approaches, ability of the radar controller to correctly position the aircraft at the high key deteriorated rapidly. The maximum vertical deviation from the high key for any of these nine flights was 2,400 feet, and the maximum lateral displacement for any of these flights was 5,200 feet.

For flights 14 to 18, pilots voiced fairly strong objections to tight maneuvers - requests by the controller for steep turns - when the aircraft was in the immediate vicinity of the high key. The pilots believed that from a point about 4,000 feet above the high key along the glide path only small turns should be made and that a straight-in approach would be preferable. This could not always be accomplished by the radar controller. Even though the guide path would not call for steep turns near the high key, the aircraft was sometimes displaced from this path, either purposely for altitude control, or inadvertently because of controller guidance lag. When this happened, the steep turns were necessary to position the aircraft at the high key.

CONCLUSIONS

An investigation of the problems associated with radar guidance of a glider from high altitudes has been made using conventional aircraft in a simulated flameout condition, standard ground-tracking radar, and a scaled wire for guidance programming on the radar plotting board. Starting altitudes ranged from 46,500 feet to 30,000 feet, and starting displacements from the high key varied from 67 nautical miles to 8.4 nautical miles. Lift-drag ratios were held constant for most of the flights; however, over the range of tests this ratio was varied from 17 to 6. Indicated airspeeds were held constant throughout each flight at either 160 or 250 knots. As a result of these tests, the following conclusions were reached:

1. A gliding vehicle having a lift-drag ratio of 16 and holding a constant indicated airspeed of 160 knots can be radar controlled to within 800 feet vertically and 2,400 feet laterally of a high key.

2. A gliding vehicle having a lift-drag ratio of 17 and holding a constant indicated airspeed of 250 knots can be radar controlled to within 800 feet vertically and 400 feet laterally of a high key.

3. A gliding vehicle having a lift-drag ratio of 6 and holding a constant indicated airspeed of 250 knots can be radar controlled to within 2,400 feet vertically and 5,200 feet laterally of a high key.

4. Radar stations which receive only azimuth-distance information are able to control the glide path of a gliding vehicle as well as stations that receive azimuth-distance-altitude information, provided that altitude information is supplied by the pilot.

5. With simple instructions, it is believed that any radar operator can control the flight of a gliding vehicle within boundaries shown in these tests.

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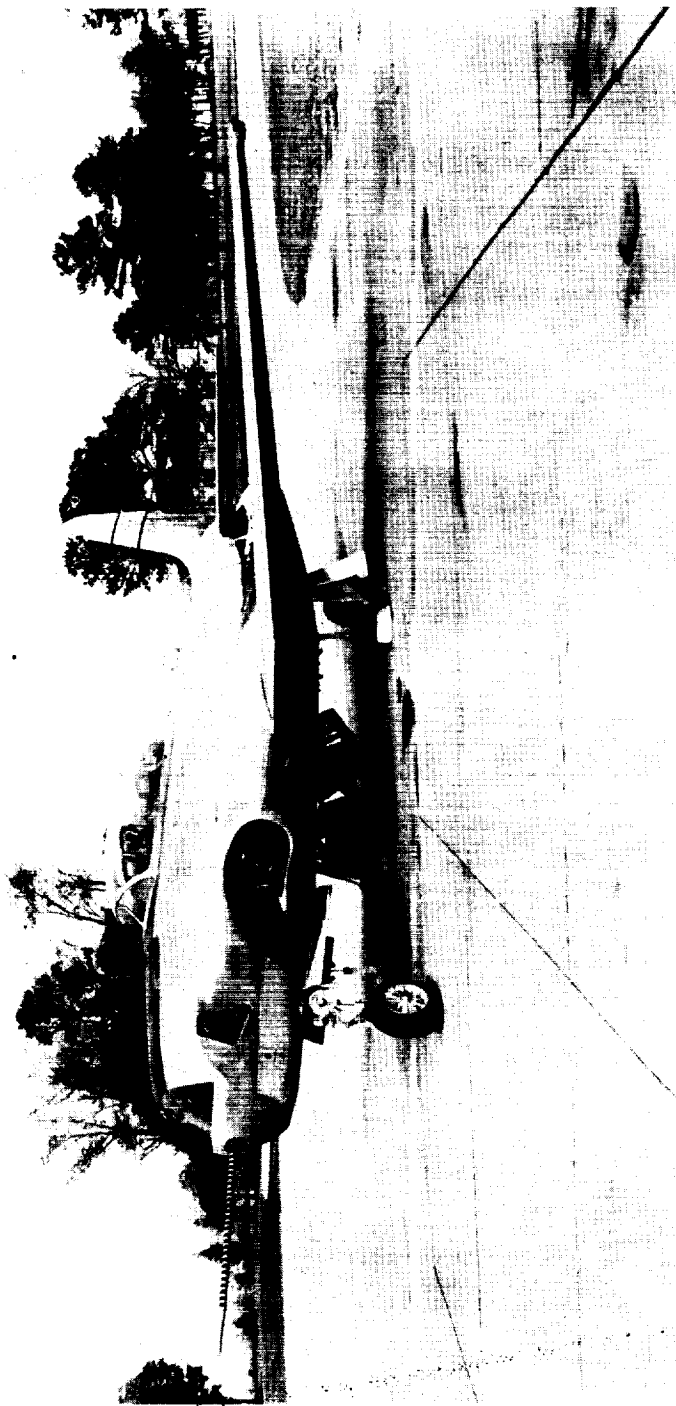
Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., May 19, 1960.

REFERENCES

1. Reeder, John P.: The Effect of Lift-Drag Ratio and Speed on the Ability to Position a Gliding Aircraft for a Landing on a 5,000-Foot Runway. NASA MEMO 3-12-59L, 1959.
2. Bray, Richard S., Drinkwater, Fred J., III, and White, Maurice D.: A Flight Study of a Power-Off Landing Technique Applicable to Re-entry Vehicles. NASA TN D-323, 1960.
3. Matranga, Gene J., and Menard, Joseph A.: Approach and Landing Investigation at Lift-Drag Ratios of 3 to 4 Utilizing a Delta-Wing Interceptor Airplane. NASA TM X-125, 1959.
4. Matranga, Gene J., and Armstrong, Neil A.: Approach and Landing Investigation at Lift-Drag Ratios of 2 to 4 Utilizing a Straight-Wing Fighter Airplane. NASA TM X-31, 1959.
5. Stillwell, Wendell H.: Results of Measurements Made During the Approach and Landing of Seven High-Speed Research Airplanes. NACA RM H54K24, 1955.

TABLE I.- APPROACHES TO HIGH KEY POSITION

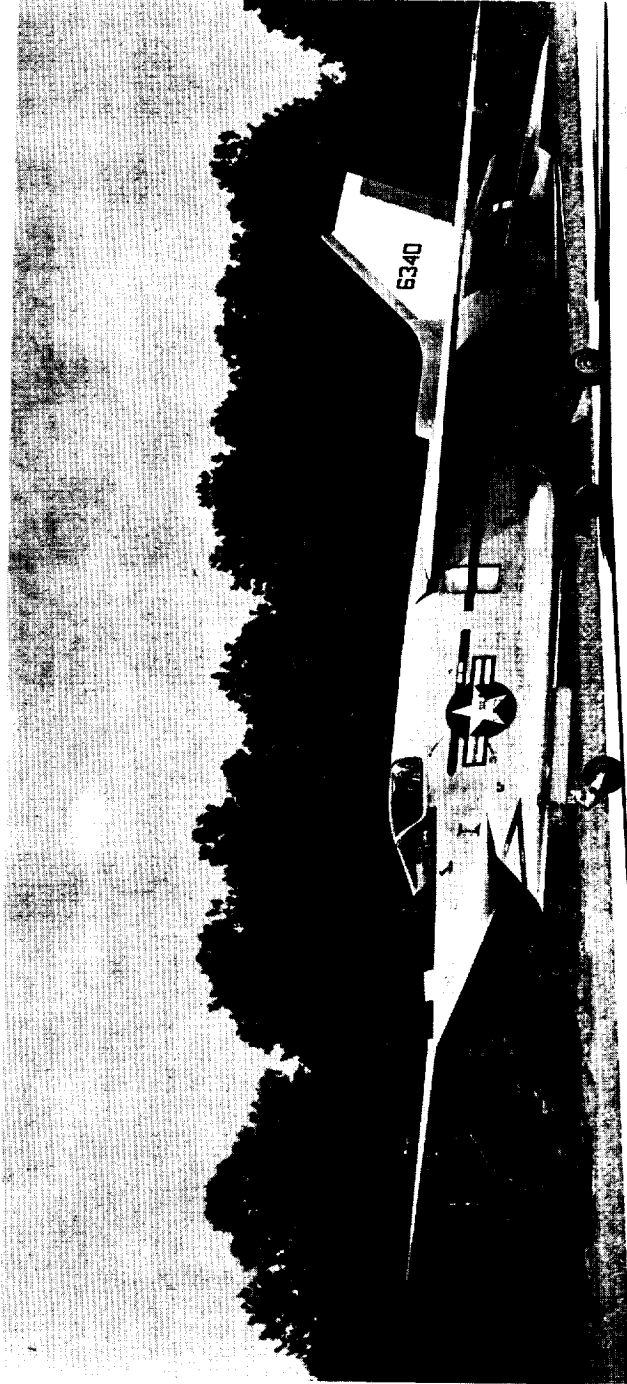
Flight	Airplane starting position			High key position		Airplane position at high key arrival			Indicated air speed, knots	Effective L/D
	Altitude, ft	Azimuth, deg	Distance from high key, nautical mile	Altitude, ft	Heading, deg	Altitude, ft	Heading, deg	Lateral distance from high key, ft		
1	34,500	205	51.7	10,000	040	12,500	090	0	160	16
2	34,500	190	59.7	10,000	040	10,300	058	2,000	160	16
3	35,000	227	57.7	10,000	040	10,200	040	1,000	160	16
4	34,000	198	54.4	10,000	040	10,200	040	1,000	160	16
5	35,000	245	8.4	10,000	220	10,000	220	0	160	16
6	33,000	259	11.0	4,000	220	4,000	220	0	160	16
7	31,000	248	32.5	4,000	220	4,000	220	1,100	160	16
8	30,000	249	40.7	4,000	220	4,400	220	1,700	160	16
9	34,000	220	67.0	10,000	040	10,800	040	2,400	160	16
10	33,000	201	43.0	10,000	040	10,100	040	0	160	16
11	34,500	224	40.0	10,000	280	9,400	280	0	250	17
12	33,000	198	44.0	10,000	280	9,200	280	0	250	17
13	34,000	270	40.8	10,000	040	10,500	040	400	250	17
14	34,900	220	19.4	10,000	040	7,600	077	4,000	250	6
15	34,900	250	20.1	10,000	040	8,600	040	1,000	250	6
16	34,600	260	9.4	10,000	040	10,000	040	5,200	250	6
17	34,000	200	19.4	10,000	040	8,600	040	1,000	250	6
18	37,700	223	27.6	4,000	040	5,200	040	0	250	6
19	35,600	208	18.4	4,000	040	2,500	067	500	250	6 - 10
20	45,000	240	44.4	12,000	040	11,800	040	0	250	6 - 11
21	46,500	225	34.9	12,000	040	9,700	049	2,000	250	6 - 11
22	42,400	247	31.6	12,000	040	11,300	040	2,000	250	6 - 11



(a) Jet trainer. L-57-4963

Figure 1.- Photographs of aircraft used in tests.

L-1063



(b) Jet fighter. L-59-6101

Figure 1.- Concluded.

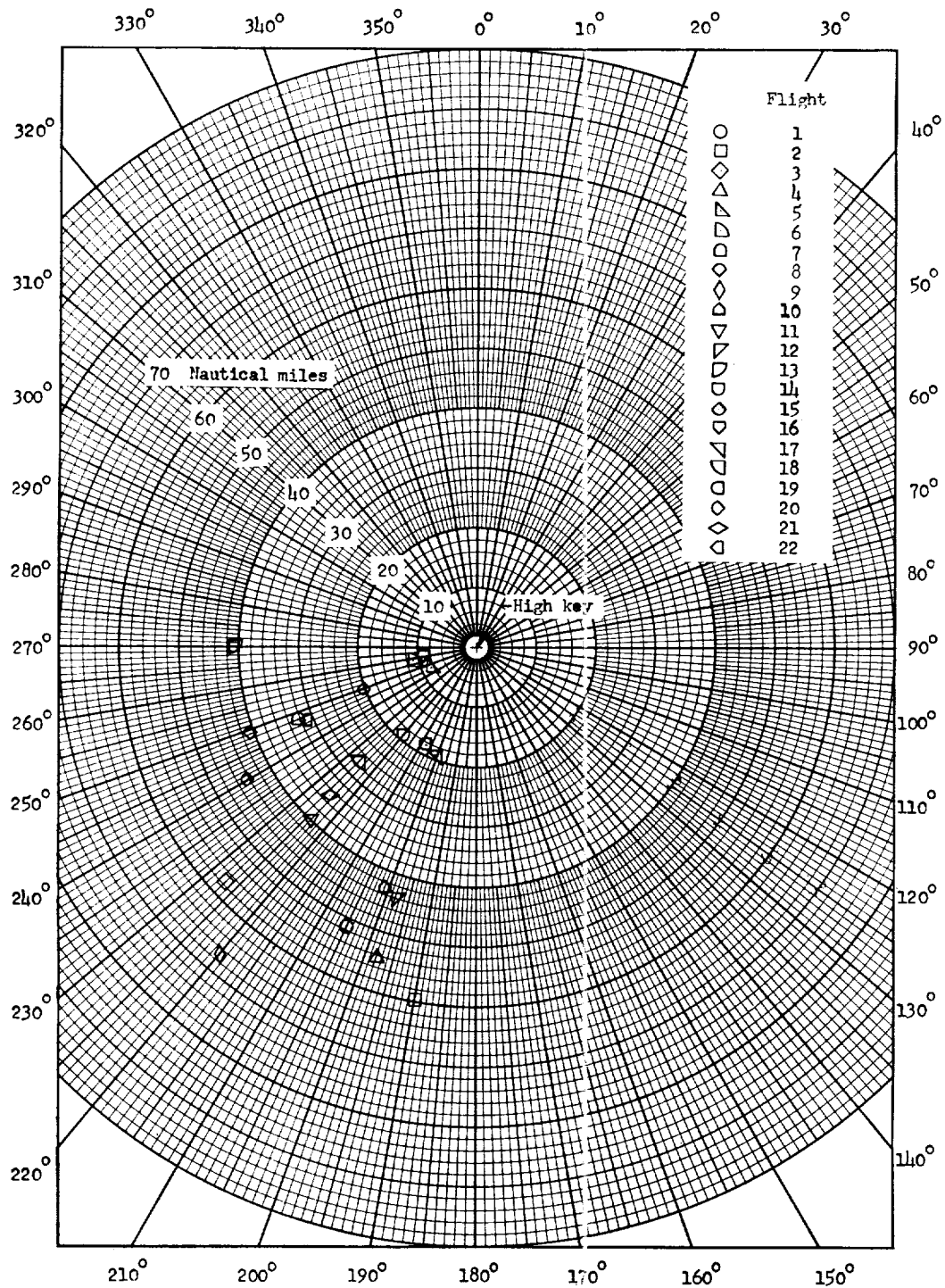


Figure 4.- Geographical starting position of radar-directed flights to high key.

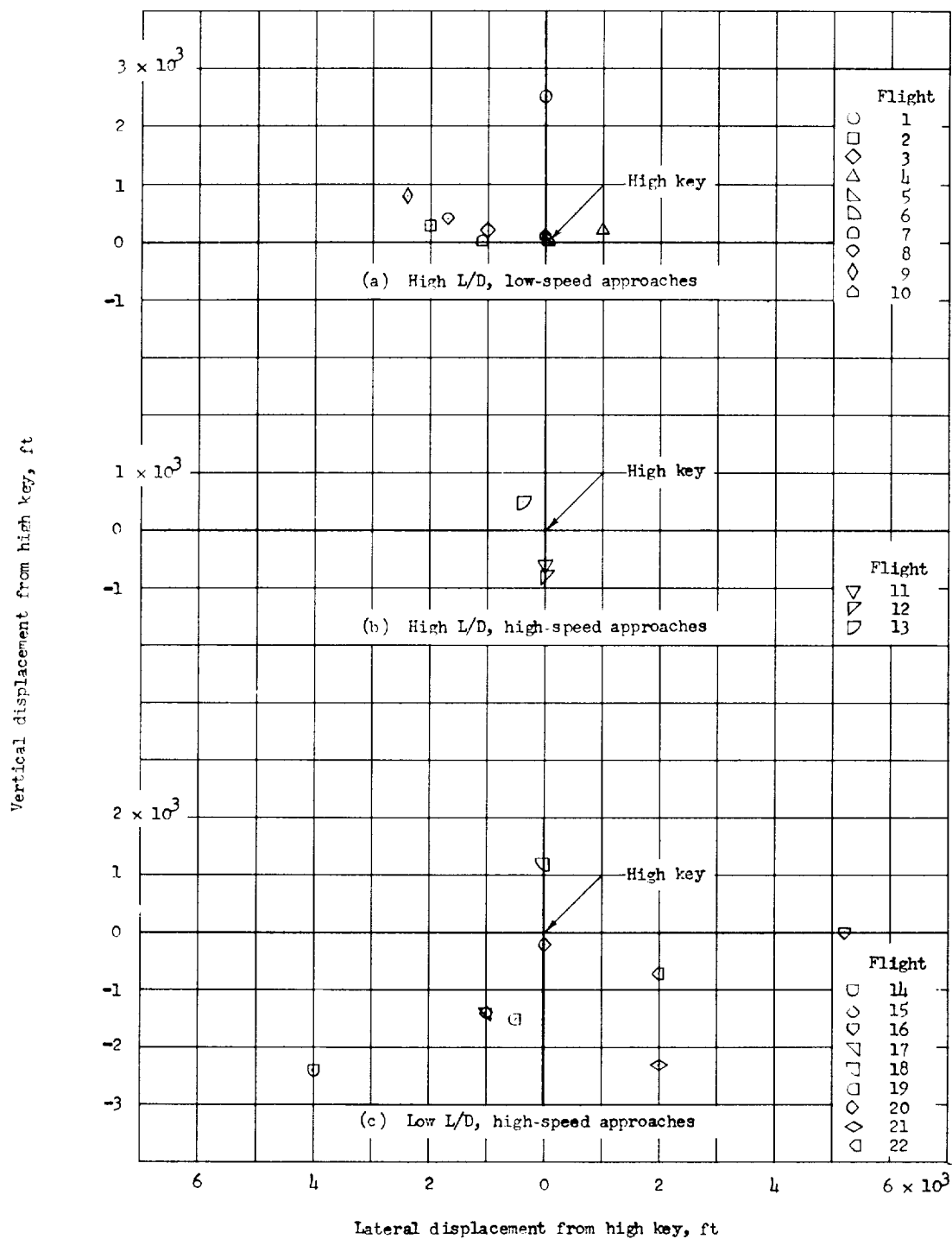


Figure 5.- Vertical plane view of the arrival displacement of the aircraft from the high key.

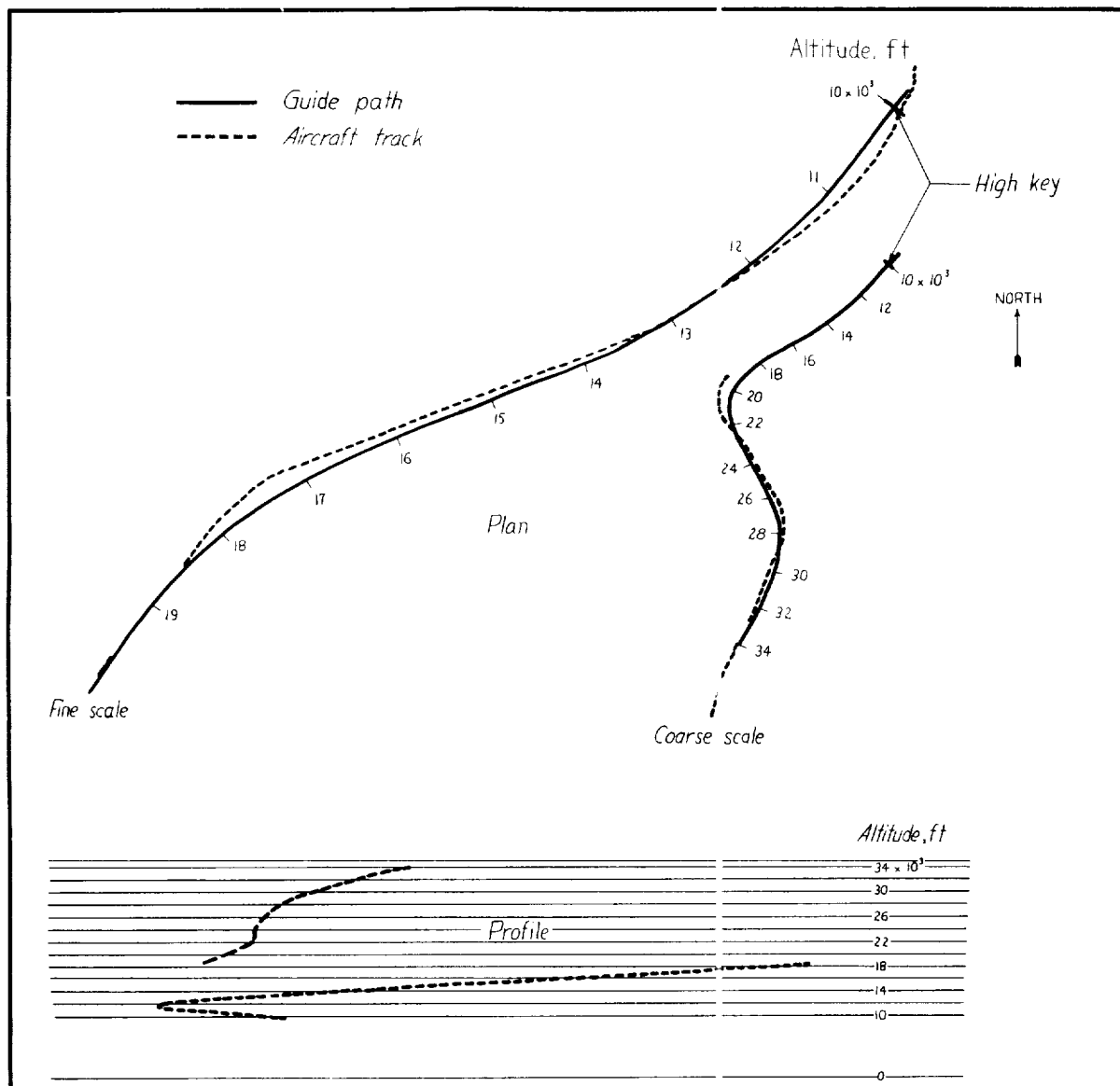


Figure 6.- Reproduction of the radar plot of a typical high L/D low-speed-approach guidance problem. $L/D = 16$; $V_i = 160$ knots; flight 4.

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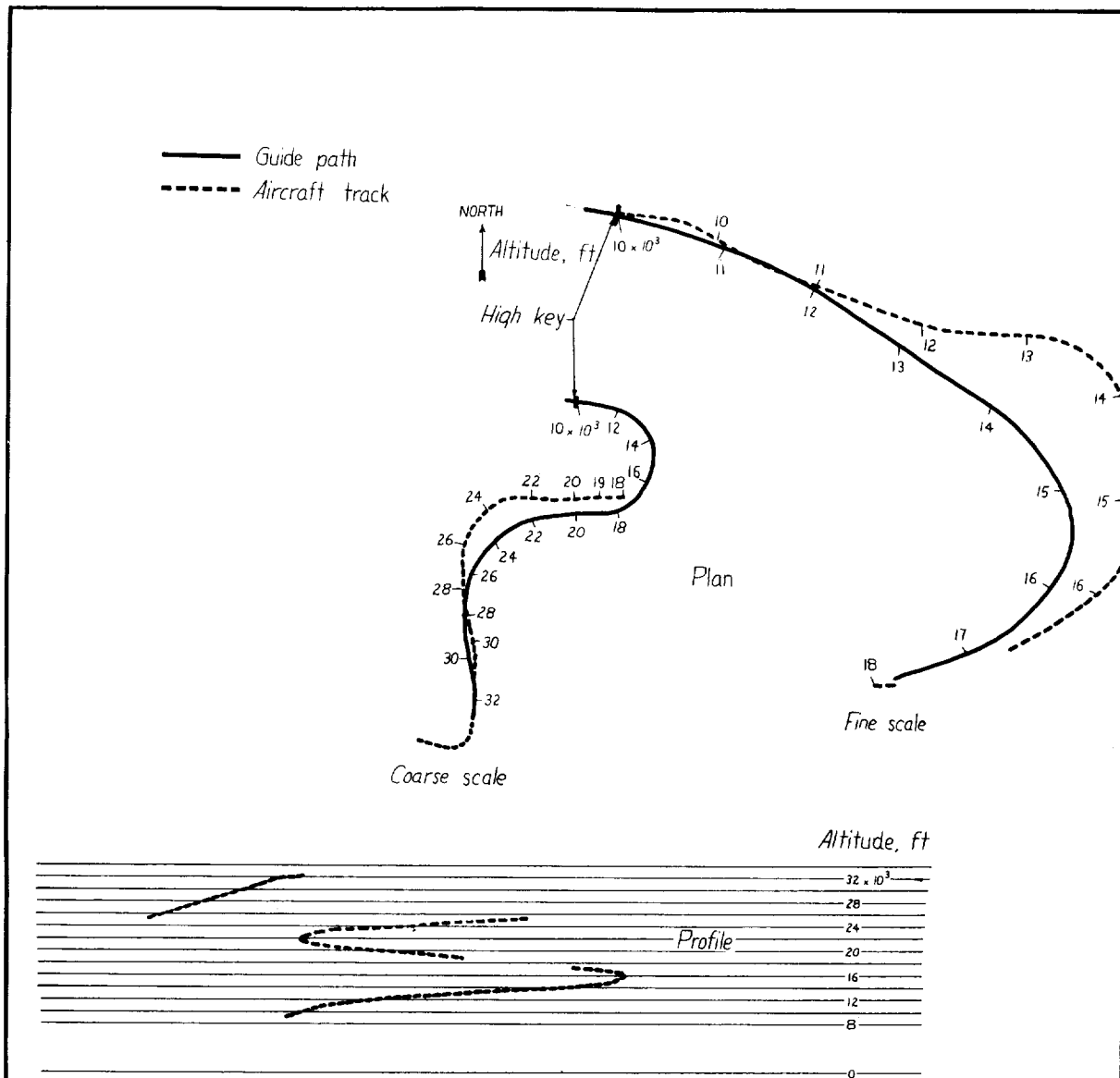


Figure 7.- Reproduction of the radar plot of a typical high L/D high-speed-approach guidance problem. $L/D = 17$; $V_i = 250$ knots; flight 12.

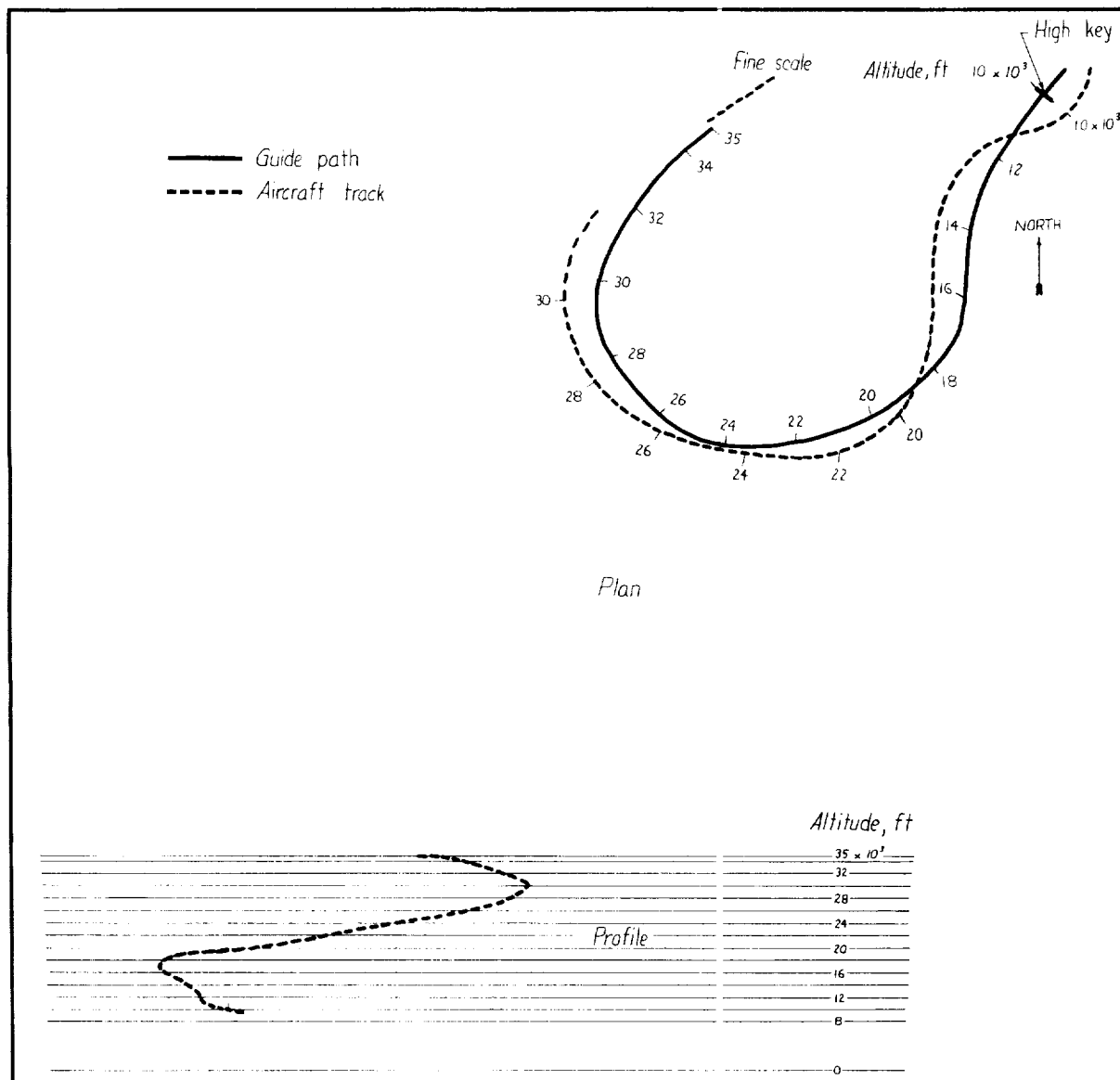


Figure 8.- Reproduction of the radar plot of a typical low L/D high-speed-approach guidance problem. $L/D = 6$; $V_1 = 250$ knots; flight 16.

